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(56) Documents cited
GB 2171212 A GB 2107140 A EP 0284198 A2
EP 0133968 A1 US 4751605 A US 4327391 A
US 4004201 A

(58) Field of search
UK CL (Edition K) H2K KDA KDX KJE KJG
INT CL^5 H02H 3/04 3/093

(54) Circuit breaker with current range indicator

(57) A circuit breaker 14 is coupled to a power line delivering electric current from a power source to a load such as a motor. When the power line is disconnected by the circuit breaker, a set of LEDs 17 indicate whether the disconnection is caused by a short-circuit current, a severe overload current, or a slight overload current flowing to the load. In addition, under the condition of a low overload current, a buzzer 19 generates an alerting sound and an LED 18 generates a blinking light before the power line is disconnected. The circuit breaker responds to the magnitude of the highest phase current, and time delay circuits are included so that tripping occurs more quickly for larger overcurrents. The LEDs 17 are energised by optically triggered triacs. A selector switch is used to set the threshold for severe overload response.

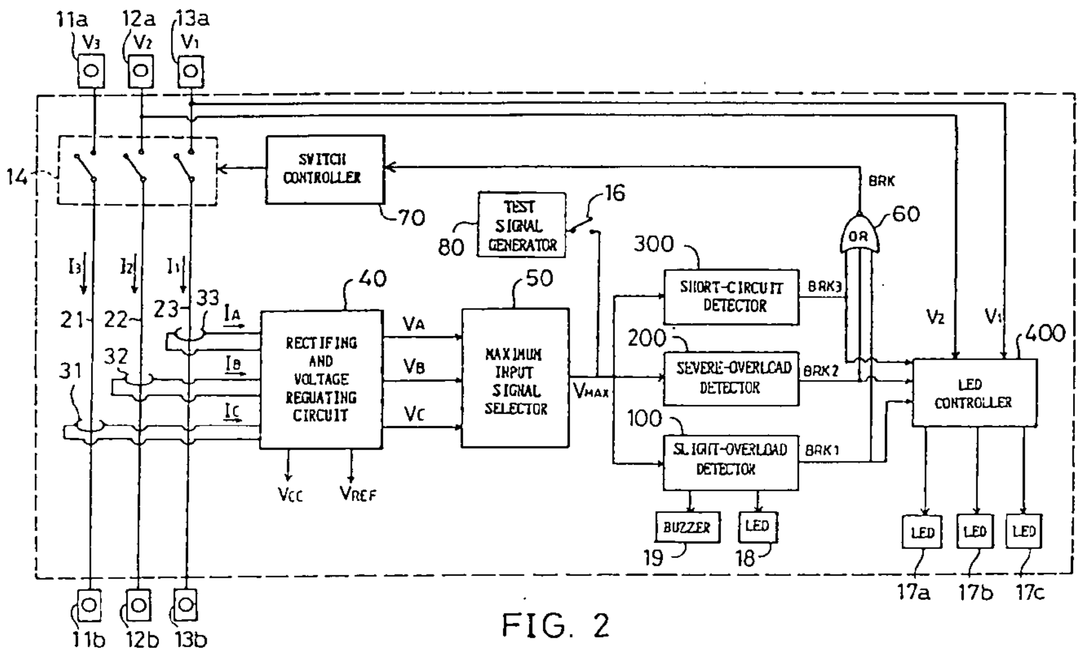

FIG. 2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

GB 2 267 190 A

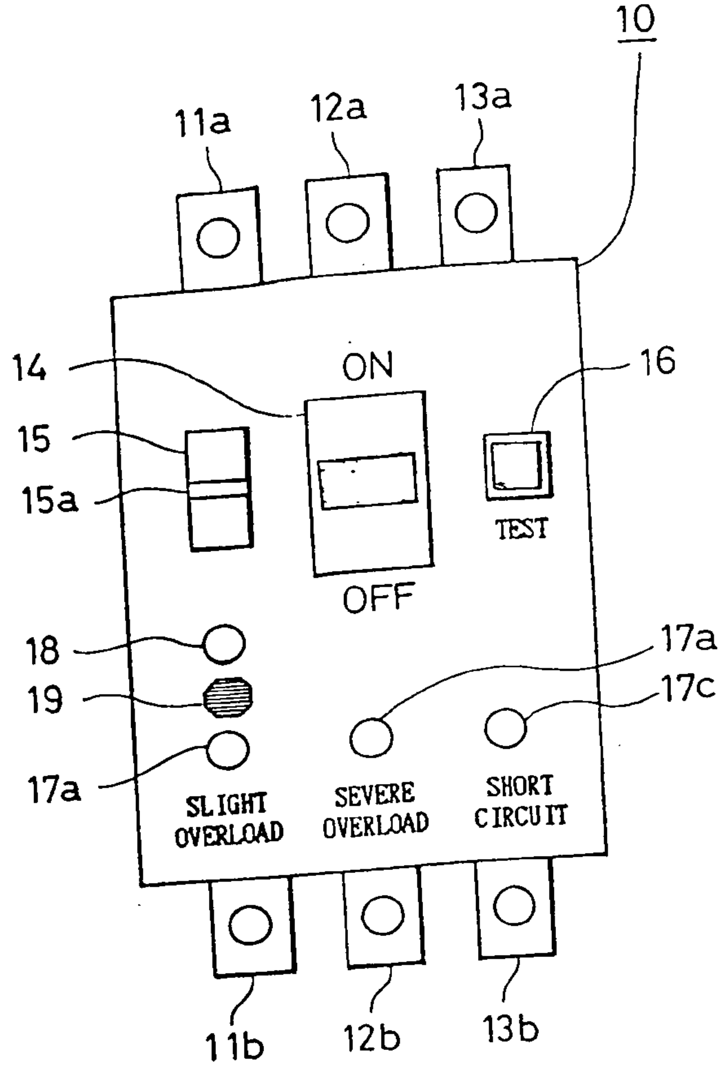
10
11a
12a
13a
14
ON
16
15
15a
TEST
OFF
18
17a
19
17c
17a
SLIGHT
OVERLOAD
SEVERE
OVERLOAD
SHORT
CIRCUIT
11b
12b
13b

FIG. 1

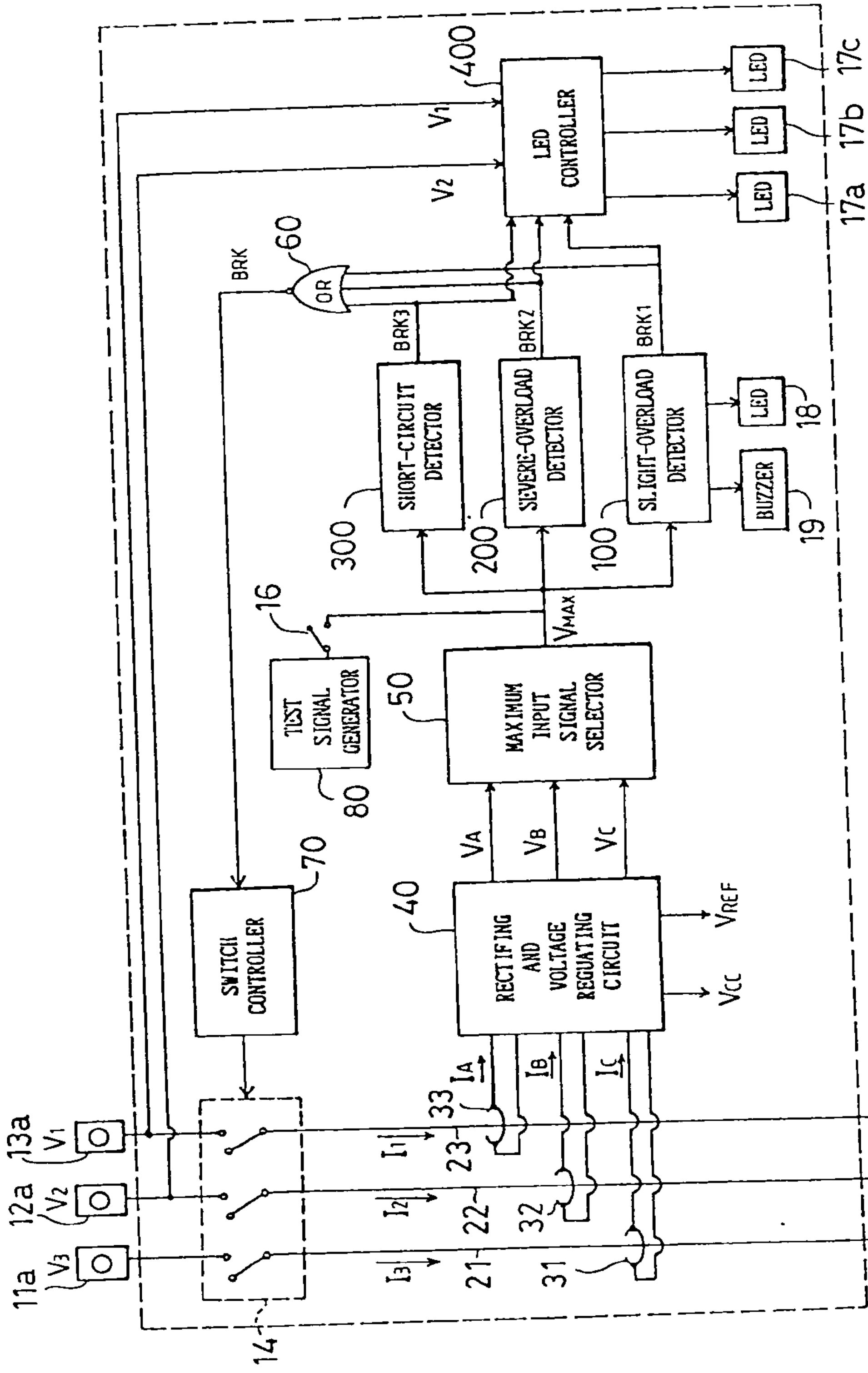
400
LED CONTROLLER
LED
17a
17b
17c
V1
V2
BRK
60
OR
BRK3
BRK2
BRK1
SHORT-CIRCUIT DETECTOR
SEVERE-OVERLOAD DETECTOR
SLIGHT-OVERLOAD DETECTOR
300
200
100
LED
18
BUZZER
19
16
VMAX
TEST SIGNAL GENERATOR
80
MAXIMUM INPUT SIGNAL SELECTOR
50
VA
VB
VC
SWITCH CONTROLLER
70
RECTIFING AND VOLTAGE REGUATING CIRCUIT
40
VCC
VREF
IA
IB
IC
33
23
32
22
31
21
I1
I2
I3
13a
12a
11a
V3
13b
12b
11b
14

FIG. 2

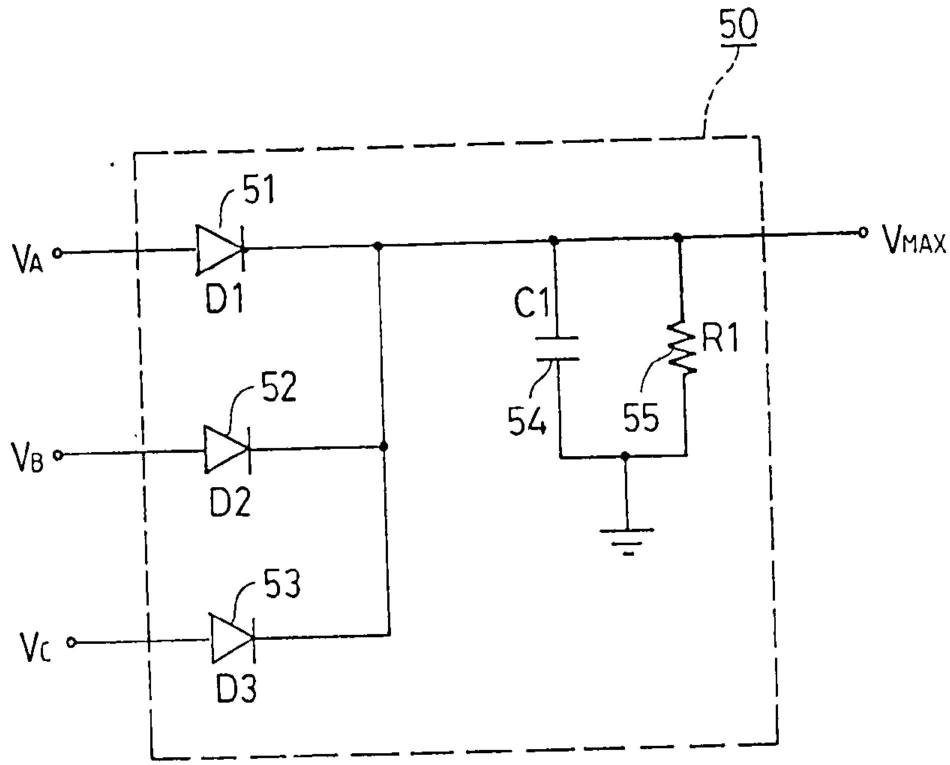

FIG. 3

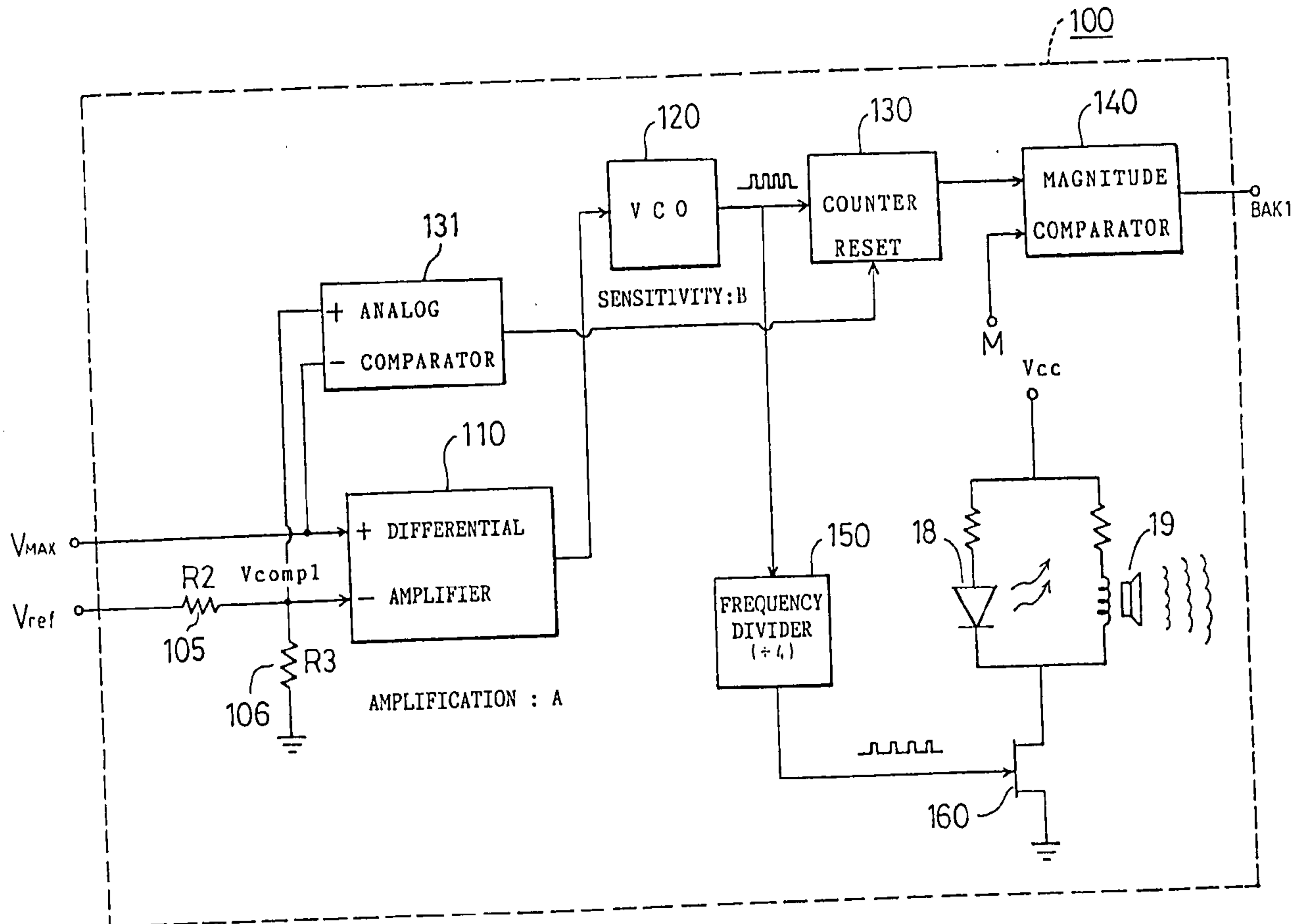
100
120
130
140
131
110
150
18
19
160
V C O
COUNTER
RESET
MAGNITUDE
COMPARATOR
BAK1
+ ANALOG
− COMPARATOR
SENSITIVITY:B
M
Vcc
+ DIFFERENTIAL
− AMPLIFIER
VMAX
Vref
R2
Vcomp1
105
R3
106
AMPLIFICATION : A
FREQUENCY
DIVIDER
(÷4)

FIG. 4

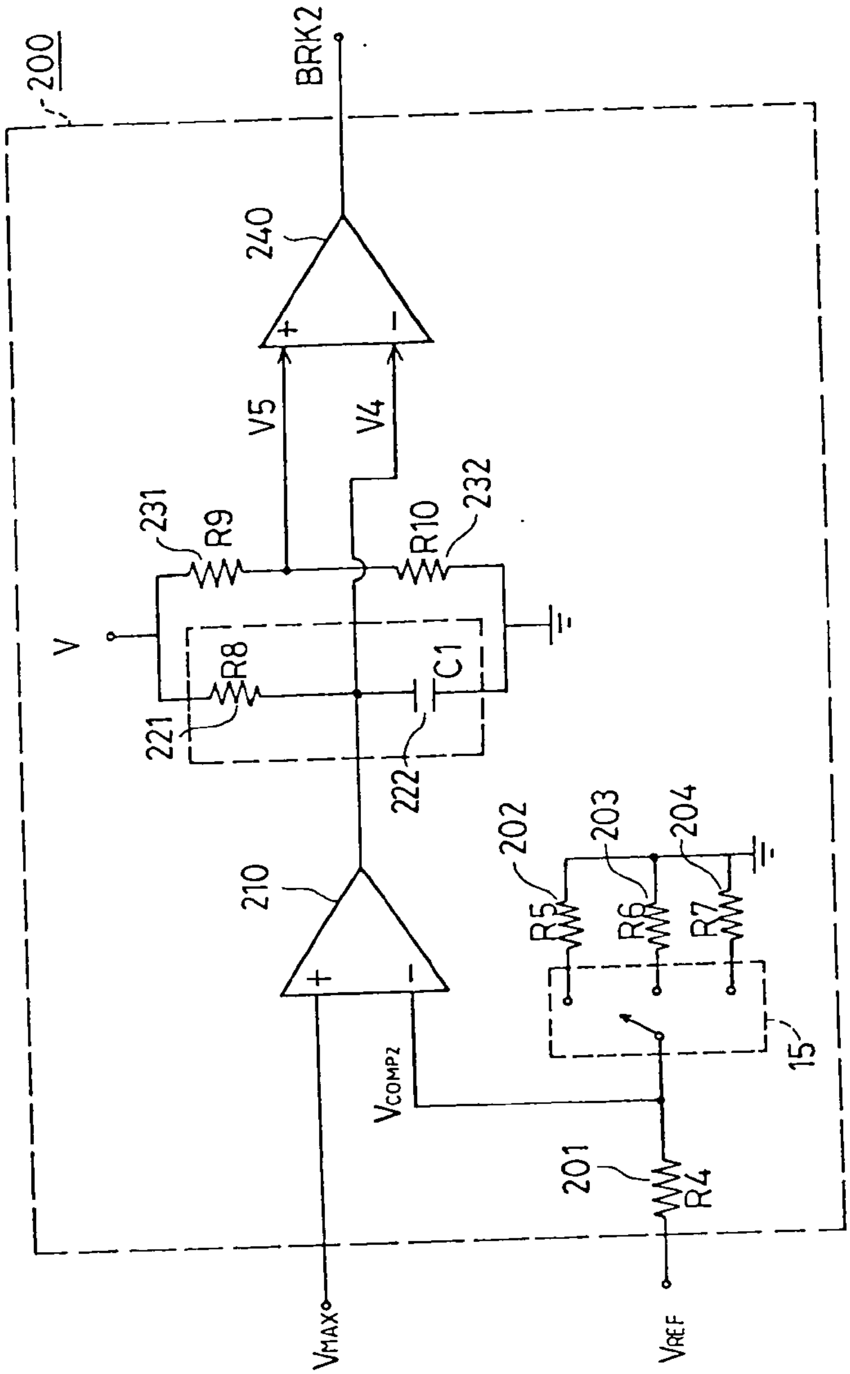
200
BRK2
240
V5
V4
231
R9
R10
232
V
R8
C1
221
222
210
202
203
204
R5
R6
R7
VCOMP2
15
201
R4
VMAX
VREF

FIG. 5

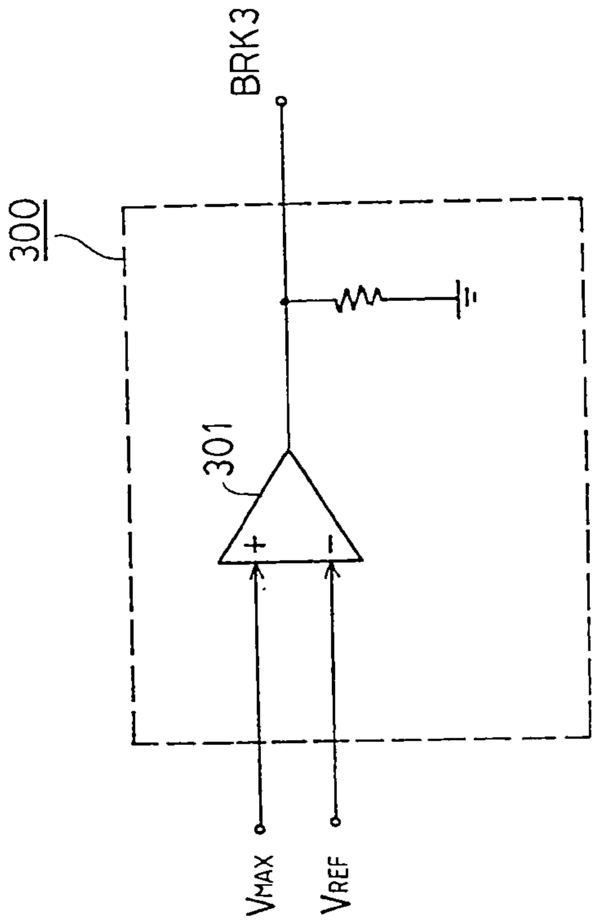

FIG. 6

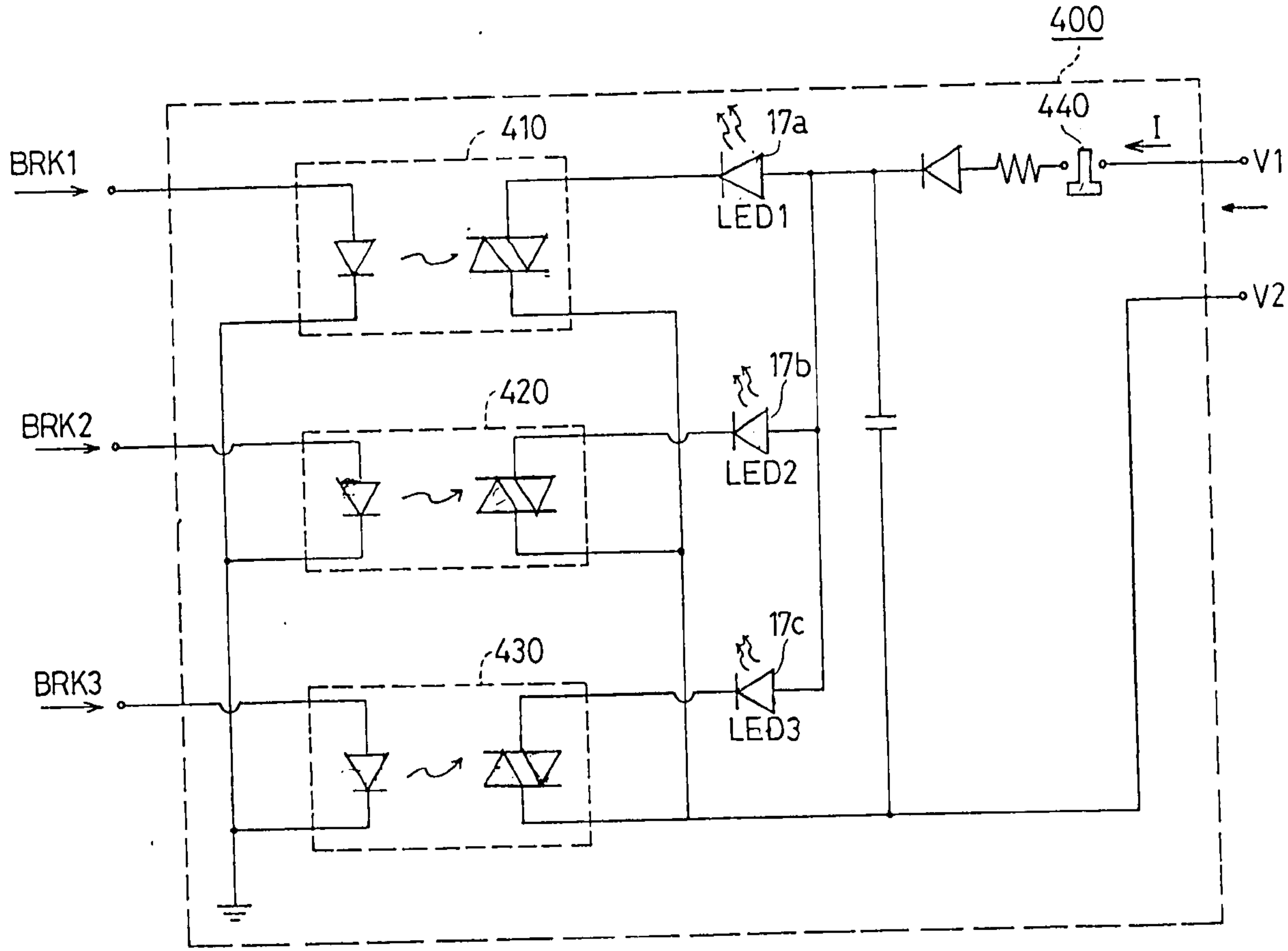
400
440
I
V1
V2
BRK1
BRK2
BRK3
410
420
430
17a
17b
17c
LED1
LED2
LED3

FIG. 7

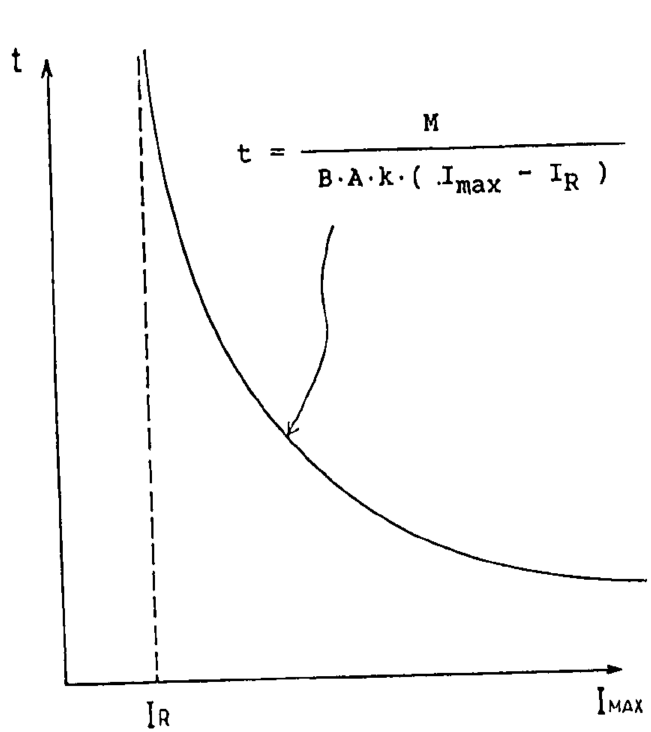
t
$t = \frac{M}{B \cdot A \cdot k \cdot (I_{max} - I_R)}$
I_R
I_{MAX}

FIG. 8A

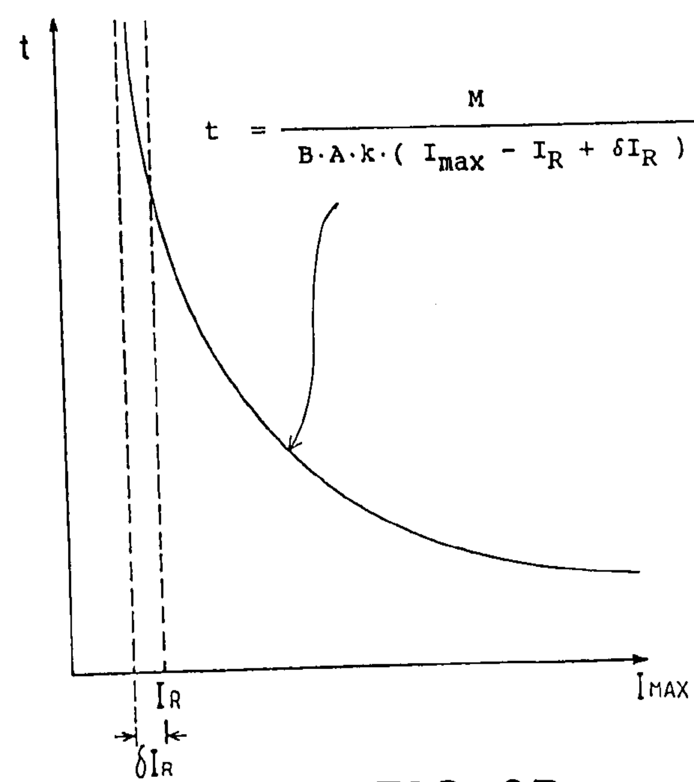
t
$t = \frac{M}{B \cdot A \cdot k \cdot (I_{max} - I_R + \delta I_R)}$
I_R
δI_R
I_{MAX}

FIG. 8B

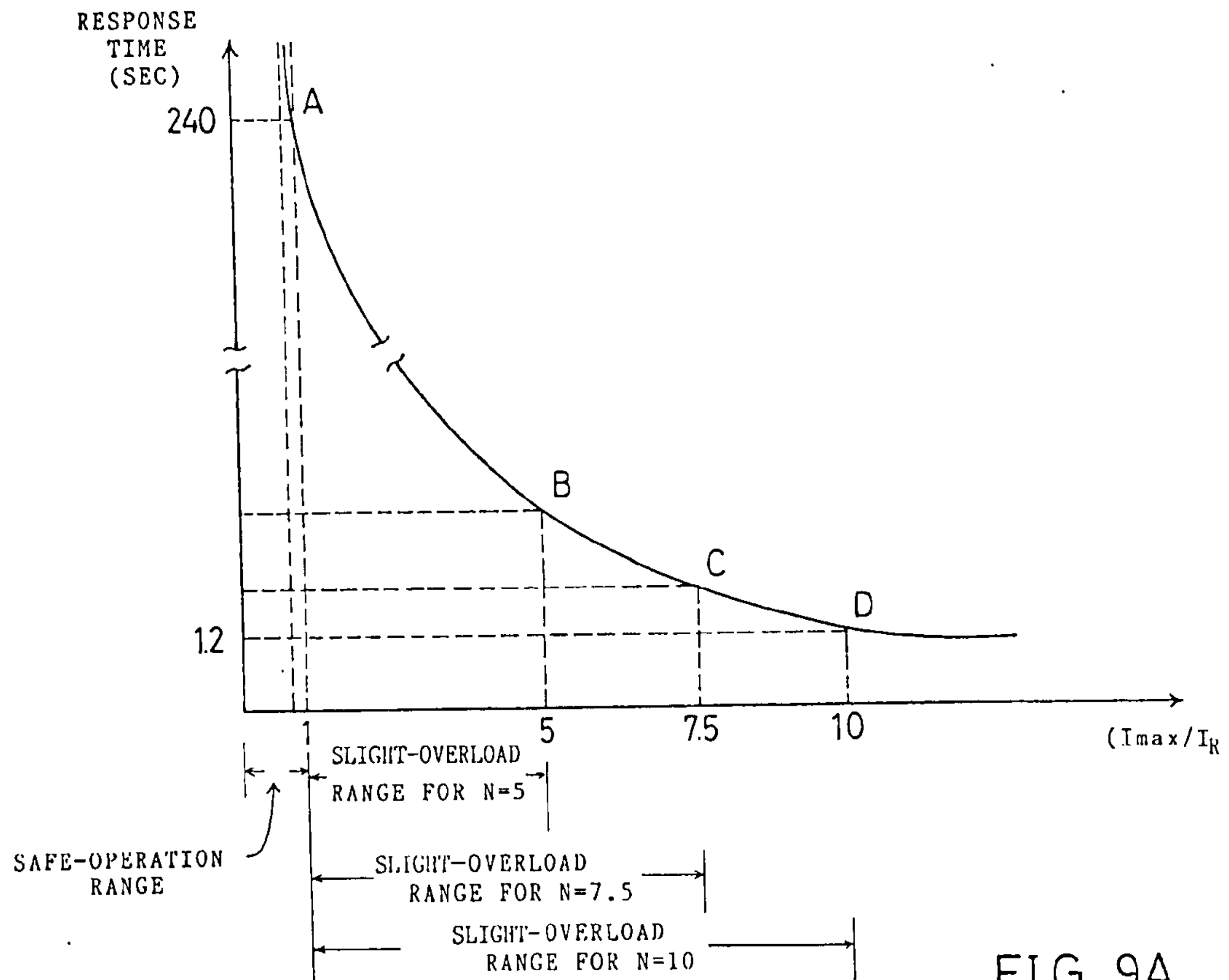
RESPONSE
TIME
(SEC)
240
1.2
A
B
C
D
1
5
7.5
10
(I_{max}/I_R)
SLIGHT-OVERLOAD
RANGE FOR N=5
SLIGHT-OVERLOAD
RANGE FOR N=7.5
SLIGHT-OVERLOAD
RANGE FOR N=10
SAFE-OPERATION
RANGE

FIG. 9A

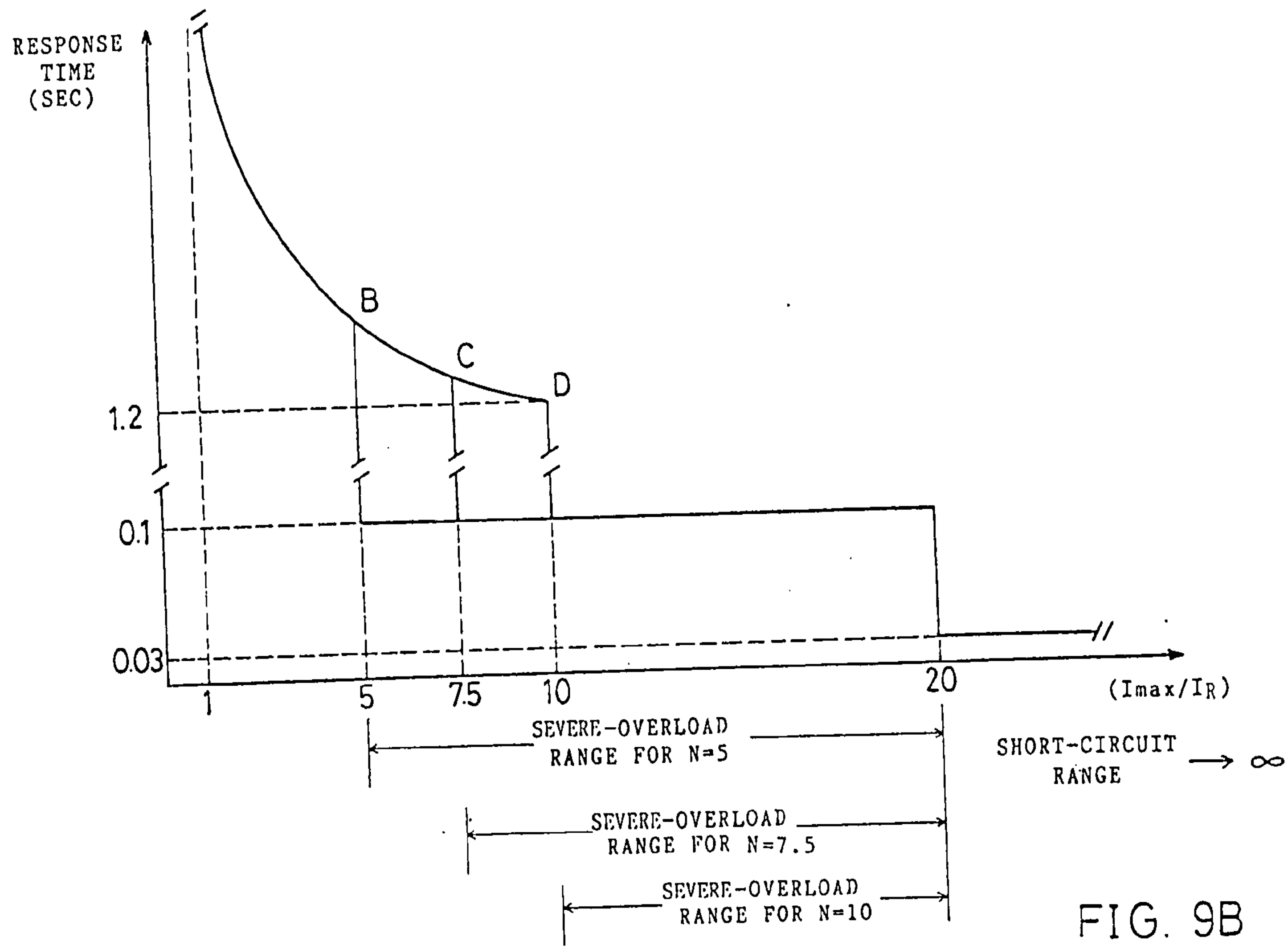
RESPONSE
TIME
(SEC)
1.2
0.1
0.03
B
C
D
1
5
7.5
10
20
(Imax/IR)
SEVERE-OVERLOAD
RANGE FOR N=5
SEVERE-OVERLOAD
RANGE FOR N=7.5
SEVERE-OVERLOAD
RANGE FOR N=10
SHORT-CIRCUIT
RANGE
∞

FIG. 9B

2267190

TITLE:

" A CIRCUIT BREAKER "

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to circuit breakers, and more particularly, to a circuit breaker which is provided with a plurality of displays for indicating whether a power line disconnection is caused by a slightly overload delivering current, by a severely overload delivering current, or by a short circuit current.

2. Description of Prior Art:

A circuit breaker is a device utilized for uncoupling a load from a power source when an overly high current is detected to be delivered from the power source to the load. Conventionally, fuses are used as circuit breakers. Since it is often inconvenient to replace a burned fuse, there are electronic circuit breakers which employ current detecting devices capable of driving a solenoid to cut off a switch coupled between the power source and the load.

When a power line is cut off by a circuit breaker, it is important for a technician to determine what has caused the circuit breaker to cut off the power line before the power line can be reconnected. If the cause is due to an overly high current flowing through the power line, i.e. an overload, the power line can be reconnected right after the load has been reduced. If the cause is due to a short-

circuit, the short-circuited part has be to found out and fixed before the power line can be reconnected again.

The conventional electronic circuit breakers are only capable of switching off the power line when an overly high current is detected and not capable of indicating whether the power line disconnection is caused by a short-circuit or by an overload. Due to this deficiency, a technician often had to check extensively through out entire network including all the power transmission lines and every circuit part of the load for the cause of the power line disconnection.

Accordingly, if the circuit breaker is provided with an indicator capable of indicating how large a delivering current has caused the power line to be disconnected, then it would be very helpful for technicians responsible for diagnosing the cause of the power line disconnection.

SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to provide a circuit breaker which is capable of indicating whether the disconnection of the power line thereby is caused by a slight overload, by a severe overload, or by a short-circuit.

In accordance with another object, the circuit breaker according to the present invention is further provided with an indicator capable of generating an alert signal when the power delivering to a load is only slightly higher the rated power for a predetermined duration. With this provision, a person can immediately reduce the load to lower the power below the rated power.

A circuit breaker in accordance with the present invention is provided with a first LED, a second LED, and a third LED. When a power line is disconnected by the circuit breaker, a person can check the LEDs for the cause of the disconnection. If the cause is by a short-circuit, the first LED is lighted; if the cause is by a severe overloading, the second LED is lighted; and if the cause is by a slight overloading, the third LED is lighted.

Further to the provision of the three LED indicators, the circuit breaker according to the present invention is provided with a buzzer and a fourth LED in association with the condition of a slight overloading. During the initial time the circuit breaker detects a slight overloading with the delivering power only slightly higher than the rated power, the buzzer is actuated to generate an alerting sound and the fourth LED is actuated to generate a blinking light for a predetermined duration before the power line is cut off and the third LED is lighted up. During this duration, a person can immediately reduce the load to lower the delivering powering and thus the power line would not be disconnected. If no one reduces the load, the circuit breaker will eventually cut off the power line after the predetermined duration.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description of the preferred embodiments thereof with references made to the accompanying drawings, wherein:

FIG. 1 shows the outer appearance of a circuit breaker in accordance with a preferred embodiment of the present invention;

FIG. 2 shows the schematic diagram of the circuit breaker of FIG. 1;

FIG. 3 shows the circuit diagram of a maximum input signal selector utilized in the circuit breaker of FIG. 1;

FIG. 4 shows the circuit diagram of a slight-overload detector utilized in the circuit breaker of FIG.1;

FIG. 5 shows the circuit diagram of a severe-overload detector utilized in the circuit breaker of FIG.1;

FIG. 6 shows the circuit diagram of a short-circuit detector utilized in the circuit breaker of FIG.1;

FIG. 7 shows the circuit diagram of the LED controller utilized in the circuit breaker of FIG.1;

FIGs. 8A-8B are two graphical representations utilized for showing the shift of a response time curve; and

FIGs. 9A-9B are graphical representations, wherein the curves represent the response time of a circuit breaker in accordance with a preferred embodiment of the present invention versus the delivering current in the power lines.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In a circuit breaker in accordance with the present invention, it is in general desired that the response time to disconnect the power line is substantially in inverse proportion to the magnitude of the delivering current, i.e. the larger the overload current, the quicker the circuit breaker disconnects the power line. As a consequence, in a preferred embodiment of the circuit breaker according to the present invention, four predetermined ranges are proposed for the delivering current, i.e. a safe-operation range, a slight-overload range, a severe-overload range, and a short-circuit range.

The safe operation range is defined as when the magnitude of the delivering current is below I_R,

the slight-overload range is defined as when the same is within the range from I_R to $N \cdot I_R$;

the severe-overload range is defined as when the same is within the range from $N \cdot I_R$ to $20 \cdot I_R$; and

the short-circuit range is defined as when the same is above $20 \cdot I_R$,

where I_R is the rated current of the power line and N is a predetermined number which can be selected either as 5, 7.5, or 10.

Referring to FIG. 1, there is shown the outer appearance of a circuit breaker 10 designed according to the preferred embodiment of the present invention. As shown in the figure, the circuit breaker 10 according to the present invention, in addition to the conventional members such as a power switch 14, a test switch 16, is further provided with a first LED 17a, a second LED 17b, a third LED 17c, a fourth LED 18, a buzzer 19, and a selection switch 15. Also shown in the figure are a set of three connectors 11a, 11b, 11c which are used to connect the

circuit breaker 10 to a 3-phase power source (not shown); and a set of three connectors 11a, 11b, 11c which are used to connect the same to the load of the 3-phase power source.

The selection switch 15 is used for the selection of the number N, which can be switched to three different positions by manually moving a lever 15a thereof. If the lever 15a is moved to a position marked by a numeral "5", the number N is set to 5; if the lever 15a is moved to a position marked by a numeral "7.5", the number N is set to "7.5"; and if the lever 15a is moved to a position marked by a numeral "10", the number N is set to 10.

In the case a delivering current from the 3-phase power source to the load is within the slight-overload range, the circuit breaker 10 will trigger the fourth LED 18 to blink and the buzzer 19 to send out an alert sound to notify the condition. A person nearby the site can therefore immediately reduce the load to lower the delivering current below the rated current value I_R. Should the delivering current has been reduced below the rated current value I_R before the response time, the power line will not be disconnected.

In the case a delivering current from the 3-phase power source to the load is within the severe-overload range, the circuit breaker 10 will disconnect the power line immediately in 0.1 sec and thereafter the second LED 17b is lighted up.

In the case a delivering current is within the short-circuit range, the circuit breaker 10 disconnects the power line immediately in 0.03 sec and thereafter the third LED 17c is lighted up.

In industrial applications, the circuit breaker in accordance with the present invention is intended to be used in association with 3-phase induction motors. At the time when an induction motor is just turned on, there is always a starting current, as high as about six times the rating current, flowing into the induction motor. The starting current may last for 0.5 sec and then falls to a normal magnitude below the rating current.

Therefore, it is a purpose of the circuit breaker 10 to provide three selectable lower limits for the severe-overload range. In the case the peak value of a starting current is, for example, equal to $6 \cdot I_R$, the lower limit of the severe-overload range should be selected at least as $7.5 \cdot I_R$ or otherwise every time the induction motor is just turned on, power line will always be disconnected. If the peak value of a starting current is about $8 \cdot I_R$, then the lower limit of the severe-overload range should be selected at least as $10 \cdot I_R$.

The purpose of using two LEDs, i.e. 17b and 17c, to distinguish the two overly high delivering current cases is that, in the case of a severe-overload delivering current, the power switch 14 of the circuit breaker 10 can be reswitched on to deliver the power again right after the load has been reduced; while in the case of a short-circuited delivering current, a technician has to undertake a thorough checking of the entire power delivering network and the circuitries of the load to find out where the short-circuit takes place and fix the same before the power switch 14 can be reswitched on. Otherwise, the power source will still deliver a short-circuit current.

Referring to FIG. 2, there is shown the schematic circuit diagram of the circuit breaker 10. The circuit breaker 10 utilizes a *slight-overload detector* 100, a

severe-overload detector 200, and a *short-circuit detector* 300 in combination for the detection of the delivering current.

Three power lines 21, 22, 23 are used to connect the power supply to the load. Each of the three power lines 21, 22, 23 is coupled respectively with a current detector 30. The current detectors 30 is of an induction type and thus the output thereof is an alternating current induced by the delivering current flowing through the associated the power line. The magnitude of the induced current is in proportional to the magnitude of the delivering current flowing in the power line. If the current flowing in the power lines 21, 22, 23, are denoted I_1, I_2, and I_3 and the induced currents are denoted I_A, I_B, and I_C, then

$$I_A = p \cdot I_1, \quad I_B = p \cdot I_2, \quad \text{and} \quad I_C = p \cdot I_3, \qquad (1)$$

where p is a fixed constant

The induced currents I_A, I_B, and I_C are received by a *voltage rectifying and regulating circuit* 40 designed to generate five DC voltage outputs: V_A, V_B, V_C, V_{REF}, and V_{CC}, where

$$\begin{aligned} V_A &= q \cdot I_A = p \cdot q \cdot I_1 = k \cdot I_1, \\ V_B &= q \cdot I_B = p \cdot q \cdot I_2 = k \cdot I_2 \\ V_C &= q \cdot I_C = p \cdot q \cdot I_3 = k \cdot I_3 \\ V_{REF} &= k \cdot 20 \cdot I_R, \end{aligned} \qquad (2)$$

q is a fixed constant and $k = p \cdot q$, and

V_{CC} is a DC voltage used as the power source to drive the circuit breaker 10.

The design of the voltage rectifying and regulating circuit 40 involves only basic AC-to-DC power conversion techniques and therefore disclosing the DC output specifications is considered to be enough to enable those who are skilled in the art of electrical engineering to design a circuit having the same functions. Accordingly, a detailed circuit configuration of the voltage rectifying and regulating circuit 40 will not be illustrated and described herein.

The voltages V_A, V_B, V_C are delivered to a maximum voltage selector 50. Although in the case of an overload the three delivering currents I_1, I_2, I_3 are increased substantially with a same factor, in the case of a short circuit, however, it is possible that only one of the power lines 21, 22, 23 is delivering a short-circuit current. Therefore, it is the duty of the maximum voltage selector 50 to compare the magnitudes of the three DC voltages V_A, V_B, V_C and select accordingly the one with the maximum magnitude as the output thereof. The output voltage of the maximum voltage selector 50 is denoted V_{max}.

The circuit configuration of the maximum voltage selector 50 is shown in FIG. 3, which includes an array of three diodes 51, 52, and 53. In a case, for example, the voltage V_1 is the maximum voltage, then the relative voltage at the cathode of the diode D1 51 is larger than that at the anode of the diode D2 52 and that at the anode of the diode D3 53. As a consequence, the diode D2 52 and the diode D3 53 are reverse biased and thus only the voltage V_1 is delivered through the RC circuit 54, 55 to the output port.

The slight-overload detector 100, the severe-overload detector 200, and the short-circuit detector 300 are utilized cooperatively in the determination of the range of the delivering current in accordance with the output voltage V_{max} of the maximum voltage selector 50. If the delivering current is within the slight-overload range, the slight-overload detector 100 is triggered to send out a digital signal BRK1=1; if the delivering current is within the severe-overload range, the severe-overload detector 200 is triggered to send out a digital signal BRK2=1; and if the delivering current is within the short-circuit range, the short-circuit detector 300 is triggered to send out a digital signal BRK3=1.

The output lines of the digital signals BRK1, BRK2, BRK3 are coupled to a 3-input OR gate 60. The output of the OR gate 60 is termed BRK. A power switch controller 70 is employed for turning the power switch 14 back to the *OFF* position and which is triggered whenever the signal BRK=1 is present. As a consequence, when one of the digital signals BRK1, BRK2, or BRK3 is 1, the power switch controller 70 is triggered. The power switch controller 70 utilizes a solenoid (not shown) for pulling the power switch 14 back to the *OFF* position and the structure thereof is a conventional technique so that a detailed description thereof will not be given.

At the same time the signal BRK is used to trigger the disconnection of the power line, the associated signal, either BRK1, BRK2, or BRK3, which trigger the signal BRK to become 1 is also sent to the LED controller 400 to light up the associated LED.

Descriptions on the detailed structures of the slight-overload detector 100 , the severe-overload detector 200,

the short-circuit detector 300, and the LED controller 400 will be given respectively below.

<u>The Slight-Overload Detector 100</u>

Referring to FIG. 4, the configuration of the slight-overload detector 100 comprises principally an analog comparator 101 with the outputs thereof coupled to a MOSFET switch 102, a differential amplifier 110, a voltage-controlled pulse generator (VCO) 120, a digital counter 130, a magnitude comparator 140, and a frequency divider 150 with the output thereof coupled to a MOSFET SWITCH 160.

The analog comparator 101 is employed for detecting whether the maximum delivering current I_{max} is within the slight-overload range, i.e. whether $I_{max} > N.I_R$. If *YES*, the analog comparator 101 actuates the conducting of the MOSFET switch 102 to allow the error voltage δV to be passed to the differential amplifier 110. The analog comparator 101 compares the voltage V_{max} with a voltage V_{comp2} which is borrowed from the circuit of the severe-overload detector 200 shown in FIG. 5 and which is equal to $N.k.I_R$.

The arrangements of the analog comparator 101 and the MOSFET switch 102 is essential since otherwise in the case of a severe-overload current or a short-circuit current the signal BRK may be actuated by the signal BRK1 earlier than by the associated signal BRK2 or BRK3 (see Eq.(6) described later for a relationship between the response time and the delivering current when the delivering current is within the slight overload range). Should this factor is not considered in the design, the circuit breaker 10 may disconnect the power lines due to a short-circuit

current but the LED 17a employed for indicating a slight-overload current is actuated. To avoid this situation from happening, when the maximum delivering current I_{max} is beyond the upper limit of the slight-overload range, i.e. $N \cdot I_R$, the voltage V_{max} is not passed to the differential amplifier 110.

The differential amplifier 110 has an amplification factor A and is employed for generating an error voltage δV whose magnitude is in proportion to the difference between the voltage V_{max} and a voltage V_{compl}. The voltage V_{compl} is formed by dividing the voltage V_{REF} with two resistors R_2 102 and R_3 103, where R_2=1.9K and R_3=100. Accordingly,

$$
\begin{aligned}
V_{compl} &= \frac{R_3}{R_2 + R_3} \cdot V_{REF} \\
&= (1/20) \cdot V_{REF} \\
&= k \cdot I_R
\end{aligned}
\qquad (3)
$$

and

$$
\begin{aligned}
\delta V &= A \cdot (V_{max} - V_{compl}) \\
&= A \cdot (k \cdot I_{max} - k \cdot I_R) \\
&= A \cdot k \cdot (I_{max} - I_R)
\end{aligned}
\qquad (4)
$$

where I_{max} is the maximum of the delivering currents I_1, I_2, and I_3.

When triggered by the error voltage δV, the VCO 120 sends out a pulse train with the frequency f thereof determined by:

$$f = B \cdot \delta V = B \cdot A \cdot k \cdot (I_{max} - I_R) \tag{5}$$

where B is the sensitivity (Hz/volt) of the VCO 120. The pulse train is sent at the same time to the frequency divider 150 and the digital counter 130.

The frequency divider 150 is used to divide the frequency of the output pulse train of the VCO 120 by four. A pulse train with a lower frequency is therefore sent to the gate of the MOSFET 160 such that the power from the voltage V_{CC} is delivered intermittently through the LED 18 and the buzzer 19. As a result, the buzzer 19 is actuated to generate a periodic alerting sound and the LED 18 is actuated to generate a blinking light. The reason for providing the LED 18 and the buzzer 19 side by side is that in a power switch board there are often installed with a number of circuit breaker so that when one of the circuit breakers detects a slight overload current, the sound generated by the buzzer 19 can be used to alert somebody nearby. And when a technician reaches the power switch board, the blinking light of the LED 18 can be used for the identification of which circuit breaker is in action.

The counter 130 is used to count the output pulses of the VCO 120. If the count of the output pulses has reached a preset number M, the digital magnitude comparator 140 coupled thereto is actuated to send out a binary signal 1, representing the signal BRK1=1, to the switch controller 70 to turn the power switch 14 to the *OFF* position. The power lines are thereby disconnected.

The response time t from the instant the maximum delivering current I_{max} is detected to the instant the

digital comparator sends out the signal BRK1=1 is given by:

$$t = \frac{M}{f}$$

$$= \frac{M}{B \cdot A \cdot k \cdot (I_{max} - I_R)} \quad (6)$$

The curve of Eq.(6) is shown in FIG. 8A. In accordance with Eq.(6), the response time t is in theory infinitive when $I_{max}=I_R$ and this implies that the power lines will never be disconnected when the maximum delivering current I_{max} is exactly equal to the rated current I_R. Consequently, the voltage V_{compl} should be reduced a little bit to shift the curve of FIG. 8A a distance δI_R to the left to form a curve with an equation of :

$$t = \frac{M}{B \cdot A \cdot k \cdot (I_{max} - I_R + \delta I_R)} \quad (7)$$

and as shown in Fig.8B. With this adjustment, the response time t can be a predetermined finite value when $I_{max}=I_R$.

In practice, however, due to inexact variations in the parameters, the shift of the curve to the left is actually carried out by fine tuning the resistors R2 105 or R3 106 to a value with which the response time t is measured to be the predetermined finite value when $I_{max} = I_R$.

In a typical industrial application, for example, I_R=100A. In this case, when the delivering current is

exactly equal to I_R=100_A, the power line is designed to be disconnected after a duration of about 240 sec.; and when the delivering current is equal to 10.I_R=1000_A, the power line is to be disconnected after a duration of 1.2 sec. The parameters M, B, A, k can therefore be selected with proper values satisfying these design requirements.

A curve of the response time t versus the maximum delivering current I_{max} in accordance with the above requirements is shown in FIG. 9A. In the slight-overload range, if N=5, the response time is in accordance with the curve segment between Point A and Point B; if N=7.5, the response time is in accordance with the curve segment between Point A and Point C; and if N=10, the response time is in accordance with the curve segment between Point A and Point C.

The Severe-Overload Detector 200

As shown in FIG. 9B, when the magnitude of the maximum delivering current I_{max} is detected to be higher than the preselect level N.I_R but below 20.I_R, i.e. within the severe-overload range, the response time to disconnect the power line is designed to be approximately 0.1 sec.

Referring to FIG. 5, the severe-overload detector 200 essentially comprising a first analog comparator 210 and a second analog comparator 240. The first analog comparator 210 is employed for comparing the voltage V_{max} and a voltage V_{comp2} which corresponds to a delivering current N·I_R. A group of resistors R4 201, R5 202, R6 203, and R7 204 are utilized for dividing the voltage V_{max} into the voltage V_{comp2}, wherein

R4 = 1 kΩ,
R5 = 3 kΩ,
R6 = 1.67 kΩ, and
R7 = 1 kΩ.

Consequently, when the selection switch 15 selects N=5, the resistor R_4 201 is connected to the resistor R_5 201 and thus:

$$V_{comp2} = \frac{R_4}{R_4 + R_5}$$

$$= (1/4) \cdot V_{REF}$$

$$= 5 \cdot k \cdot I_R;$$

when the selection switch 15 selects N=7.5, the resistor R_4 201 is connected to the resistor R6 203 and thus:

$$V_{comp2} = \frac{R_4}{R_4 + R_6}$$

$$= (7.5/20) \cdot V_{REF}$$

$$= 7.5 \cdot k \cdot I_R;$$

and when the selection switch 15 selects N=10, the resistor R4 201 is connected to the resistor R_7 204 and thus:

$$V_{comp2} = \frac{R_4}{R_4 + R_7}$$

$$= (1/2) \cdot V_{REF}$$

$$= 10 \cdot k \cdot I_R$$

When $V_{max} < V_{comp2}$, indicating that $I_{max} < N.I_R$, the output of the analog amplifier 210 is a fixed low voltage V(0), and when $V_{max} > V_{comp2}$, indicating that $I_{max} > N \cdot I_R$, the output of the analog amplifier 210 is a fixed high voltage V(1).

Intermediate the first analog comparator 210 and the second analog comparator **240** is there coupled an RC timing circuit 220. The RC timing circuit 220 consists of a resistor R_8 221 and a capacitor C_1 222, and which is designed with a timing constant $R_8 \cdot C_1$ = 20ms. The purpose of the RC timing circuit 220 is to be used as a delay of the output signal of the first analog comparator 210. When the analog amplifier **210** sends out the fixed high voltage V(1), the capacitor 222 is charged. The voltage V_4 spanning the capacitor 222 compared with a fixed voltage V5 formed by dividing the voltage V_{CC} with a pair of resistors R_9 231 and R_{10} 232. When the voltage V_4 is greater than the fixed voltage V_5, the second comparator 240 sends out a high voltage V(1), representing the signal BRK2=1. The duration from the appearance of the output voltage V(1) of the first analog comparator 210 to the appearance of the output voltage V(1) of the second comparator 240 is substantially $4R_8C_1$ = 80ms.

The Short-Circuit Detector 300

When the magnitude of the maximum delivering current I_{max} is detected to be higher than $20.I_R$, i.e. within the short-circuit range, the response time to disconnect the power line is designed to be as quick as possible.

Referring to FIG. 6, the short-circuit detector 300 comprises only an analog comparator 301 which compares the voltage V_{max} with the voltage V_{REF}. When the voltage

V_{max} is smaller than the voltage V_{REF}, the output of the analog comparator 301 is a low voltage representing a digital signal BRK3=0; and when the voltage V_{max} is greater than the voltage V_{REF}, the output of the analog comparator 301 is a high voltage representing a digital signal BRK3=1. The duration, from the detecting of the delivering current by the current detectors 30 to the turn-off of the power switch 14 is about 0.03 sec. As shown in FIG. 9B, this duration is therefore the response time of the circuit breaker 10 to disconnect the power lines within the short-circuit range.

The LED Controller 400

Referring to FIG. 7, the LED controller 400 includes three photo-triggered TRIACs 410, 420, 430, each of which is coupled to one of the LEDs 17a, 17b, 17c. The LED controller 400 utilizes the power extracted from the power lines 22 and 23. The reason for doing this is that when the power switch 15 is switched off due to an overly high delivering current, causing V_{CC}=0, the LED controller 400 still can fetch electric power form the power source to light up one of the LEDs 17a, 17b, 17c.

In a case, for example, the signal BRK1=1 is present to the LED controller 400, the photo-triggered TRIAC 410 is triggered to be conducted. As a consequence, current is delivered through the associated LED 17a to light up the same. Despite that the power switch controller 70 is turned off at this time, causing V_{CC}=0 and BRK1=0, the current is still delivering to the LED 17a since it is the characteristic of the photo-trigger TRIAC 410 to maintain in conducting state once it is fired.

The LED controller 400 further includes a reset switch 440. The reset switch 440 normally is switched on to allow power connection of the LED controller 400 to the power lines 22, 23 such that whenever one of the photo-triggered TRIACs 410, 420, or 430 is fired, current can be delivered to the associated LED. When a problem causing a power line disconnection has been fixed and the power switch 14 of the circuit breaker 10 is switched to the *ON* position again, the LED that has been lighted up should be reset to go off. To achieve this purpose, every time the power switch 14 is turned from the *OFF* position of the *ON* position, the reset switch 420 is triggered thereby to be switched off for a shore duration of about 2-3 seconds. As a result, the current flowing through the LED that has been lighted up is cut off and thus the associated photo-triggered TRIAC is reset to become like an open switch.

The test switch 16 is used to test if the circuit breaker 10 is operable. As shown in FIG. 2, the test switch 16 is coupled between a test signal generator 80 and the detectors 100, 200, 300. The test signal generator 80 is also energized by the voltage V_{CC}. When the test switch 16 shown in FIG. 1 is pressed, i.e. turned on, the test signal generator 80 sends out a DC current with a fixed magnitude I_{TEST}. The magnitude of I_{TEST} is predetermined to simulate a short-circuit current such that the short-circuit detector 300 is triggered to turn off the power switch 14.

The present invention has been described hitherto with an exemplary preferred embodiment. However, it is to be understood that the scope of the present invention need not be limited to the disclosed preferred embodiment. On the contrary, it is intended to cover various modifications and similar arrangements within the scope defined in the

following appended claims. The scope of the claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A circuit breaker coupled to a power line, said power line transmitting electric power from a power source to a load, said circuit breaker comprising:

means for detecting the magnitude of a delivering current flowing through the power line;

means for disconnecting the power line when the magnitude of the magnitude of the delivering current exceeds a predetermined level;

means, triggered only when the power line is disconnected, for indicating a range of the delivering current.

2. A circuit breaker according to Claim 1, wherein said detecting means comprises:

a *slight-overload detector* for detecting if the magnitude of the current is within a first predetermined range;

a *severe-overload detector* for detecting if the magnitude of the current is within a second predetermined range; and

a *short-circuit detector* for detecting if the magnitude of the current is within a third predetermined range; and

said disconnecting means disconnecting the power line after a first predetermined duration if the magnitude of the current is within the first predetermined range;

said disconnecting means disconnecting the power line after a second predetermined duration it the magnitude of the current is within the second predetermined range; and

said disconnecting means disconnecting the power line after a third predetermined duration if the magnitude of the current is within the third predetermined range.

3. A circuit breaker according to Claim 2, wherein said slight-overload detector comprises:

means for generating an alerting signal within the first predetermined duration.

4. A circuit breaker according the Claim 3, wherein said alerting signal generating means includes:

a *buzzer* for generating an alarm sound; and

an *LED* for generating a blinking light.

5. A circuit breaker according to Claim 2, wherein said severe-overload detector comprises:

a *first comparator means* for detecting whether the delivering current flowing through the power line with a predetermined threshold, said first comparator means generating a first signal if the delivering current flowing through the power line is above the predetermined threshold, said circuit breaker disconnect the power line in response to the first signal; and

a *time delay means*, coupled to the output of said first comparator, for delaying the output of the first signal with a predetermined interval.

6. A circuit breaker according to Claim 2, wherein said indicating means includes:

a *first LED* which is lighted up when the disconnection of the power line is caused by a delivering current within the first predetermined range;

a second LED which is lighted up when the disconnection of the power line is caused by a delivering current within the second predetermined range; and

a third LED which is lighted up when the disconnection of the power line is caused by a delivering current within the third predetermined range.

7. A circuit breaker substantially as described referring to and as shown in the accompaying drawings.

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P~tents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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(i) UK Cl (Edition K) H2K (KDA, KDX, KJE, KJG)

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Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

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Documents considered relevant following a search in respect of claims 1-7

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2171212 A	(CONTROL LOGIC) See page 1 lines 58-62	1
X	GB 2107140 A	(FERETTINI) See page 2 lines 60-99	1, 6
X,Y	EP 0284198 A2	(WESTINGHOUSE) See column 8 line 27 - column 9 line 46 and column 18 line 52 - column 19 line 7	X: 1, 2, 5, 6 Y: 3, 4
X,Y	EP 0133968 A1	(MITSUBISHI) See Figure 6 and page 13 lines 17-24	X: 1 Y: 3, 4
X	US 4751605 A	(MERTZ) See column 2 line 65 - column 3 line 14 and column 4 lines 1-12	1
Y	US 4327391 A	(GRZEBIELSKI) See column 2 lines 3-11 and column 5 line 40 - column 6 line 43	3, 4
X,Y	US 4004201 A	(DEPUY) See column 3 line 45 - column 5 line 8	X: 1, 2, 5, 6 Y: 3, 4

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

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&: Member of the same patent family, corresponding document.

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